

pinned magnetic layer is directly laminated on the antiferromagnetic layer in the case illustrated herein. In place of the simple structure, also employable are Synthetic antiferromagnetic structures. For example, in place of 2.5 nm CoFe/7 nm IrMn, employable are 3 nm CoFe/0.9 nm Ru/3 nm CoFe/7 nm IrMn, 3 nm CoFe/0.9 nm Cr/3 nm CoFe/7 nm IrMn, etc. The thickness of two pinned layer may be different each other.

The antiferromagnetic film may be of any material of PtMn, NiMn, RuRhMn, CrMn, FeMn, NiO, etc. The material of the pinned magnetic layer may be any of Co or NiFe.

The nonmagnetic underlayer is not limited to only metal films of Ta, etc. For example, oxide films of TaO_x or the like are also employable. Using the underlayer of TaO_x in place of Ta gave the same good results. In this case, electrons not reflected on the MR-improving layer could be reflected on the interface of TaO_x underlayer/MR-improving layer in which the potential difference is large, whereby the MR ratio in the film was much more increased. However, if CoFe is formed directly on the underlayer of TaO_x, it could not be oriented in fcc(111) orientation or could not have a satisfactory fcc-d(111) spacing favorable to magnetostriction control. As opposed to the case, a underlayer of TaO_x /Au/Cu is good in practical applications. In place of TaO_x, also employable are other oxides of Ti, Zr, Cr, W, Hf, Nb, etc. Further employable are nitrides such as TiN, TaN.

Example b:

In this Example b, produced was a spin valve film of 5 nanometer Ta/1 nm Au/1 nm Cu/4 nm CoFe/2.5 nm Cu/2.5 nm CoFe/7 nm IrMn/0.5 nm Au/ 0.5 nm Cu/5 nanometer Ta, in the same manner as in Example a.

The lattice constant of the Au/Cu laminate film, which is the upper MR-improving layer, is nearer to that of IrMn, than that of the laminate film of CoFe/Cu/CoFe. Therefore, forming the laminate of Au/Cu on IrMn stabilizes more the lattice constant of IrMn, whereby the thermal stability of the film is much more improved. Disposing the Au layer directly below the protective film of Ta gives a structure where the Au layer having small surface energy is directly below the Ta layer having large surface energy. In that structure, Au readily diffuses into Ta to degrade the thermal stability of the film. Therefore, disposing Au or Ag directly below Ta is unfavorable. Like in this Example, it is desirable that the Ta protective film is formed via the Cu layer. An alloy layer of AuCu gives the same good results.

Example c:

In this Example c, produced was a spin valve film of 5 nanometer Ta/5 nm NiFeCr/1 nm Au/1 nm Cu/3 nm CoFe/2.5 nm Cu/2.5 nm CoFe/7 nm IrMn/5 nanometer Ta, in the same manner as in Example 1. In this spin valve film, the free layer is of a laminate film of 5 nm NiCoFe and 3 nm CoFe as separated

by Au/Cu existing therebetween.

As one comparative case to this Example, prepared was a spin valve film of 5 nanometer Ta/5 nm NiFeCr/3 nm CoFe/2.5 nm Cu/2.5 nm CoFe/7 nm IrMn/5 nanometer Ta also in the same manner as above.

The comparative spin valve film had an MR ratio of 8.6 % in the as-deposited condition, but after having been annealed at 250°C for 4 hours, its MR ratio lowered to 6.6 %. The MR ratio reduction was 23 %. This is because CoFe and NiFeCr form solid solution in this structure. In the as-deposited comparative film, the constituent elements are not mixed so much in the CoFe/NiFeCr interface and the film had a high MR ratio. However, after annealed at 250°C for 4 hours, the CoFe/NiFeCr interface was readily disturbed. In this comparative case, added was about 4 % of Cr to NiFe for current shunting in NiFeCr. The same results were also obtained in the case having $\text{Ni}_{81}\text{Fe}_{19}$ (at.%).

As opposed to the comparative case, interposing the Au/Cu laminate film between CoFe and NiFeCr as in the case of this Example 3 prevents the element diffusion in the interface therebetween. As a result, the as-deposited film of Example 3 had an MR ratio of 8.7 %, and even after annealed at 250°C for 4 hours, the annealed film still had an MR ratio of 8.1 %. This, in this film, the MR ratio reduction after annealing is well retarded. One reason for this is that, owing to the